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ABSTRACT

Research supports skin temperature changes (increases) as indicators of stress reduction or relaxation. To study the utility of skin temperature at the wrist as a measure of relaxation, 226 seventh grade students recorded their wrist temperatures before and after a 15-minute relaxation training exercise each morning for 29 weeks. Teachers checked to ensure that the student properly recorded the temperatures, and an observer from the research team visited each classroom at least once every 2 weeks. Results showed that wrist temperatures increased significantly during the relaxation exercises, and that the increases grew larger as the study continued, indicating that students learned to relax more fully with more practice in the program. The study helps validate the use of wrist temperatures as a practical measure of relaxation (or stress) for researchers, or as a biofeedback technique for individuals. (LLL)

AN EXPLORATION OF THE RELATIONSHIP BETWEEN WRIST TEMPERATURE AND RELAXATION TRAINING[1]

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Abstract

This study assesses the utility of skin temperature at the wrist as a measure of relaxation which is both inexpensive and easily obtained with existing technology. Before and after a fifteen-minute relaxation training exercise each morning for 29 weeks, 266 middle school students recorded their wrist temperatures. Temperatures increased significantly between the two measures. Also, the increases grew larger as the study continued. The study helps establish wrist temperature as a valid measure of relaxation in that the temperatures behave as hypothesized concomitant to relaxation training.

Key words:

wrist temperature

relaxation training

An Exploration of the Relationship between Wrist Temperature and Relaxation Training

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Direct measures of an organism's stress or one's state of relaxation do not exist, but the two constructs, stress and relaxation states, are well enough defined and common, in everyday usage as well as in research, that few researchers avoid them and most feel comfortable with them. Research activity in both stress and relaxation is intense. The research operationalizes the constructs with such indirect, but concededly related variables as brain wave rhythms, muscle tension, galvanic skin response, blood pressure, heart rate, respiration rate, and skin temperature, usually finger or wrist temperature. The use of wrist temperature to operationalize the relaxation state will be shown to be particularly appropriate in research on large groups because of its low cost and ease of observation. Human subjects can be used to make reliable observations of their own wrist temperatures using low-cost readily available wrist temperature bands.

The rationale which posits a logical linkage between relaxation or stress level and one's skin temperature at the wrist is essential to this paper's purpose. To establish this rationale, a brief examination of the physiology of skin temperature follows.

The temperature of the human skin at the wrist is clearly a function of at least three variables: (1) the temperature of the tissue just beneath the skin; (2) the temperature of the medium (usually air) on the surface of the skin; and (3) the thermal conductivity of the skin. Temperatures of wrist tissue and surrounding medium are necessarily interrelated except where the skin is a perfect insulator (which it never is), because heat is exchanged between the wrist tissue and the surrounding medium. Usually, and always in the present study, the flow of heat is from the tissue to the air, since the tissue is warmer. The surrounding medium in the study was the air in a middle school classroom, usually conditioned at the early hour when observations were made to a comfortable temperature near 72 ^{o}F. For purposes of discussion, one may regard such air, heated or cooled by external equipment, to be a fairly reliable heat sink, absorbing calories from the children in the study without undergoing appreciable changes in temperature.

The temperature of the wrist tissue is affected by chemical and biological processes in the tissue and by fluids, particularly blood, passing through the tissue. Since mammals regulate the temperature of blood in the trunk or central part of the body with considerable precision, the blood within the trunks of healthy children may be regarded as constant in temperature. Temperature regulation is accomplished in part by using the skin, a factor to be examined shortly. As blood leaves the trunk and is pumped through an arm or other extremity, its temperature is far more subject to variation than in the well-controlled trunk. In the present study, the blood lost heat in the arm to the

cooler surrounding air. The exact degree of cooling need not be known to infer with certainty that, given time to equilibrate, the exchange of heat between wrist and surrounding air would settle at a steady rate, producing a steady skin temperature, a phenomenon well known to observers of wrist temperature. If the rate of blood flow between trunk and wrist were increased, one would expect the temperature of the skin at the wrist to increase in the direction of the trunk temperature, since any sample of blood would remain away from the trunk's replenishing heat for a shorter period. As the flow decreases, the skin temperature would vary in the direction of the surrounding air, cooling to the ambient temperature when the flow was stopped entirely.

Important to skin temperature is the skin's vasculature (King and Montgomery, 1980). The skin consists of a superficial layer of tissue called the epidermis and a deeper portion of tissue known as the dermis, covering a subcutaneous layer of adipose tissue. Cutaneous circulation allows for the conduction of heat from the internal structures of the body to the skin so that heat can be removed from the body when required. The skin has an extensive subcutaneous venous plexus, which holds large quantities of blood that can heat the surface of the skin. Arteriovenous anastomoses, vascular communication between the arteries and the venous plexuses, constrict to reduce blood flow into the venous plexuses and dilate to increase flow. The arteriovenous anastomoses are governed by the central nervous system and reflex influences from temperature receptors.

At this point, the relationship between stress or relaxation level and blood flow rate must be established to complete the

rationale of using wrist temperature to measure a state of stress or relaxation. The amount of blood flow is largely brought about by relaxation or contraction of the smooth muscle cells lining the outside of the blood vessels (Best and Taylor, 1965). These smooth muscle cells are controlled by the state of the hypothalamus and other parts of the limbic system within the brain through nerve pathways of the sympathetic and parasympathetic nervous system, which ultimately connect to the blood vessels.

Events interpreted by a person as stressful cause constriction (nonstressful events cause dilation) of the smooth muscles lining the surface of arteries, arterioles, and some veins (Ouroboros, 1983). The sum of a large number of these local constrictions causes the blood pressure to rise dramatically and the skin temperature to lower dramatically. The dramatic change triggers the brain to send a message to the adrenal glands to secrete adrenalin in preparation for bodily defense.

Another important consideration concerning skin temperature is the state of voluntary muscular tension of the individual (Ouroboros, 1983). When the large skeletal muscles are tensed, an actual squeezing of the associated blood vessels may occur, restricting the blood flow, raising the blood pressure, and lowering the skin temperature with much the same effect as the autonomic arousal mechanism.

In addition to skin temperature adjusting to regulate the temperature for the core of the body, the fight-flight response, and the voluntary tension levels, researchers recognize such

factors as skin condition, climate, and ambient (surrounding) temperature (King and Montgomery, 1980). Ambient temperature appears to be particularly important when precise measurements are needed.

Research findings dealing with skin temperature changes as a direct result of attempts to induce stress or relaxation are supportive of the rationale. Mittelman and Wolff (1939, 1943) first reported decreases in finger temperature in patients when emotional stress was induced. Crawford, Friesen, and Tomlinson-Keasey (1977) found finger temperatures decreased under cognitively induced anxiety in subjects who discussed the anxiety-producing topics. Boudewyns (1976) found finger temperature increased under relaxed conditions and decreased under stress conditions. Further, Maslach, Marshall, and Zimbardo (1972) found skin temperature changed significantly following hypnotic suggestions. Matthews (1982) related wrist temperature to another commonly used measure of the relaxation state, brain wave rhythms in a study of alpha rhythms (8 to 12 cycles per second). While the correlation between brain wave frequency aggregated over a ten minute period and wrist temperature was significant (and negative, as anticipated), the magnitude was slight ($r = -.12$) indicating the numerous other influences on both measures.

The present study employed children ages 12 to 14 to obtain wrist temperatures. Suter and Loughry-Machado (1981) determined skin temperature could be used with children as well as adults; children controlled skin temperature better than their parents in a biofeedback situation.

While skin temperature is theoretically linked to the stress level of the individual, its effectiveness as a measure of the stress/relaxation state is demonstrated more effectively in the present research than previously. To study the relationship between the relaxation state and wrist temperature, researchers designed this study with three goals: (1) to implement a relaxation training program using wrist temperatures with a large sample to determine whether this method is practical and efficient for research using groups of students; (2) to amass descriptive data on wrist temperatures over an extended time; and (3) to examine the hypothesis that wrist temperatures will increase concomitant to exercises believed to promote relaxation.

Sample

The population was seventh grade students in 10 public and private middle schools in a four-county area in the midlands of South Carolina. The schools ranged from urban to rural with the socioeconomic levels of the parents from low to middle class. The sample consisted of 266 students (127 girls and 139 boys; 138 blacks and 128 whites).

Procedure

The students strapped a wrist temperature indicator[2] to their wrists each morning as they entered homeroom. The wrist

[2] Wrist temperature indicators can be purchased from Bio-Temp Products, 1950 West 86th St., Indianapolis, Indiana 46260.

temperature indicator is worn like a wrist watch; a sensitive liquid crystal indicator is firmly held against the underside of the wrist. The teacher conducted typical morning school business, allowing approximately ten minutes for the temperature reading to stabilize. Studies showed that the liquid crystal indicator on the wrist bands underwent rapid change at first, stabilizing to a reading which was steady in about two minutes within the range of temperature observed in the study. Then the students recorded their initial wrist temperatures. In an 18-hour workshop before the beginning of school, teachers were trained to monitor wrist temperature readings and present the relaxation exercises. In addition to training in the presentation of relaxation exercises, the teachers received a project manual including a daily curriculum. The curriculum consisted of a structured program of relaxation exercises on audio tapes. The audio-taped relaxation exercises, developed especially for middle school students, included such techniques as the quieting reflex, autogenics, and visual imagery (Lupin, 1977; Holland, 1980; Charlesworth, 1981; Matthews, 1982; see Matthews, 1984, for detailed relaxations techniques and daily curricula). The teacher conducted one relaxation exercise of approximately 15 minutes each morning. Following the relaxation exercise, the students recorded their final wrist temperatures.

The procedure occurred daily for 29 weeks, resulting in over 25,000 individual observations of wrist temperature change. Teachers checked to ensure that students properly recorded the temperatures and an observer from the research team visited each classroom at least once every two weeks.

Results

Table 1 presents the means of the initial, final, and difference (final minus initial) wrist temperatures for each class. All temperature measures are reported in degrees Fahrenheit. The mass of observations supporting these site means assures the researcher of data with excellent reliability, even for individual measures of relatively low reliability. Means differ from site to site as follows: the mean initial measures varied 1.80; the mean final measures varied 1.92; and the mean differences varied 0.47, using 11 observations in each case. A weak association (r=-.39) was observed between initial means and difference means; when the initial mean was higher, the change in temperature between readings tended weakly to be lower.

Insert Table 1 about here

With the site used as the unit of analysis (n = 11), a dependent t-test was conducted between the initial and final means to determine whether the increase in wrist temperatures was statistically significant. The observed value of t, 18.64, was significant at the pre-established .05 level of significance (the exact probability of the t-value is less than .0001). Wrist temperatures significantly increased during the relaxation exercises.

Table 2 reports the means for the initial, final, and difference temperatures for each of the 29 weeks of the project.

There is an increase (positive difference) for each of the 29 weeks. Also, there is a general trend toward larger increases over time. The relationship between the elapsed time of the study and the mean change in wrist temperatures was strong (r=.76).

Insert Table 2 about here

The only measure of ambient temperature available was the outdoor morning temperature averaged for each week. The outside ambient temperature was most closely associated with initial wrist temperatures (r=.82). Apparently, the 10-minute warm-up period prior to the relaxation training exercises was insufficient for total adjustment to the room temperature. Table 3 reports the ambient temperature along with the associated initial, final, and difference wrist tempeature means in ascending order of the ambient temperature. The associated rise in wrist temperature is evident.

Insert Table 3 about here

The ratio of the variance of the wrist temperature changes across elapsed time in the study to the average variance within each week provided a reliability coefficient (stability) for wrist temperatures. The reliability coefficient was .979.

Conclusions and Recommendations

The consistent and relatively large increases in wrist temperatures during a 15 minute relaxation exercise period suggest a fairly close relationship between changes in wrist temperatures and changes in the degree of relaxation or tension in the body, as hypothesized. Thus wrist temperature seems to be a promising physiological measure of an unobservable construct. It should be noted that there was no control group to determine if wrist temperatures increased for some extraneous reason, but there existed no visible or plausible causes that the researchers could determine other than ambient temperature. An intriguing relationship was observed between the wrist temperature and the outside temperature, despite the time allowed for the skin temperature to adjust to the room temperature. It may be that a longer period of time is required for skin temperature to adjust to indoor temperature, indicating a long-term effect of ambient temperature. Considering the high relationship found, the authors recommend allowing time to adjust to the room temperature and obtaining the ambient room temperature whenever measuring skin temperature. Procedures such as analysis of covariance or partial correlation could be employed to remove the effect of ambient temperature.

The daily increase in wrist temperatures tended to grow larger during the course of the study. This increase over time seems to indicate a practice effect. If, in fact, the increases in wrist temperature were due to participation in the relaxation exercises, then it appears that students learn to relax more

fully with more practice in the program.

This study helps validate the use of wrist temperatures as a measure of relaxation (or stress) whether as a measure for researchers or as a biofeedback technique for the individual. Also, the successful implementation of the program on such a large scale and within an existing institutional setting helps establish wrist indicators as a practical measure.

Further study is essential if researchers are to successfully quantify what is, at best, an inexact science. The effects of outdoor and room temperatures, how wrist temperatures could be used as biofeedback, and procedures for controlling other extraneous influences require careful scrutiny.

Table 1

Wrist Temperature Means

Class	N *	Initial Mean	Final Mean	Difference Mean
1	1280	89.17	92.34	3.17
2	1557	86.71	89.73	3.02
3	2901	89.20	91.29	2.09
4	1409	83.89	86.30	2.44
5	2965	89.50	92.56	3.06
6	2556	87.75	89.59	1.84
7	1550	88.88	91.91	3.03
8	2482	86.74	88.84	2.12
9	2215	87.20	90.11	2.90
10	3674	90.36	92.66	2.31
11	2728	88.04	90.77	2.73

* N represents the number of observations, <u>not</u> independent subjects, used in computing the means.

Table 2

Mean Wrist Temperatures by Weeks

Week	Initial Mean	Final Mean	Difference Mean
1	89.36	91.18	1.82
2	88.56	90.81	2.27
3	89.88	91.96	2.07
4	89.23	91.56	2.33
5	88.69	91.16	2.48
6	87.93	90.54	2.62
7	89.44	91.81	2.37
8	88.09	90.53	2.44
9	87.59	90.28	2.69
10	89.08	91.87	2.79
11	89.77	92.24	2.47
12	88.09	90.52	2.45
13	87.81	90.17	2.38
14	87.45	89.93	2.47
15	86.19	88.78	2.59
16	87.76	90.51	2.75
17	88.21	90.93	2.72
18	87.44	90.13	2.69
19	87.69	90.47	2.78
20	88.08	90.83	2.75
21	88.04	90.75	2.71
22	88.48	91.32	2.84
23	88.17	90.75	2.58
24	87.44	90.17	2.74
25	86.99	89.74	2.74
26	90.05	93.01	2.96
27	87.82	90.54	2.72
28	87.22	89.92	2.70
29	87.61	90.38	2.77

Table 3

Weekly Mean Wrist Temperatures Ordered by Ambient Temperature

Ambient Mean	Initial Mean	Final Mean	Difference Mean
20.4	86.19	88.78	2.59
27.0	87.44	90.13	2.69
29.6	87.45	89.93	2.47
29.6	87.69	90.47	2.78
29.8	87.76	90.51	2.75
30.6	87.81	90.17	2.38
33.2	87.22	89.92	2.70
36.2	87.93	90.54	2.62
36.4	87.44	90.17	2.74
36.6	88.09	90.53	2.44
36.6	88.21	90.93	2.72
37.4	87.59	90.28	2.69
37.6	88.04	90.75	2.71
39.8	86.99	89.74	2.74
40.2	88.08	90.83	2.75
43.2	89.08	91.87	2.79
43.8	88.09	90.52	2.45
44.2	88.17	90.75	2.58
44.6	87.61	90.38	2.77
47.8	88.48	91.32	2.84
48.4	88.69	91.16	2.48
49.2	87.82	90.54	2.72
50.2	89.44	91.81	2.37
50.8	89.77	92.24	2.47
51.4	90.05	93.01	2.96
53.0	88.56	90.81	2.27
55.6	89.36	91.18	1.82
55.8	89.23	91.56	2.33
56.6	89.88	91.96	2.07

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